AN INEXPENSIVE HIGH VOLTAGE PROBE*

by

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ABSTRACT

A simple, easily constructed, high voltage probe ($\lesssim$ 300 kV) with a good frequency response ($\lesssim$ 100 MHz) and high input impedance ($\gtrsim$ 10 kΩ) is desirable in many applications. Such a probe, constructed of two concentric cylinders of "Velostat"[1] is reported.

Introduction

There are several well-known voltage divider techniques employed as high voltage probes. A capacitive and an inductive divider are shown in Fig. 1. Both suffer from high frequency ringing noise caused by the ever present stray reactances. They also place a reactive loading on the measured circuit that is often undesirable because the loading is frequency dependent. The more familiar resistive divider, as shown in Fig. 2, has a limited frequency response because the signal may be shunted directly to ground by the stray capacitances and especially the variable stray capacitances. Decreasing the total chain resistance tends to improve the high frequency response; however, to prevent loading down the input circuit the total resistance should be as large as possible. Typical resistive dividers have a total resistance of $\lesssim$100 kΩ and a frequency response of $\lesssim$500 kHz.

The high frequency response can be improved by placing the resistive divider chain in a known electric field to decrease the effect of the variable stray capacitances. Two methods for doing this are shown in Fig. 3. A cylindrical metal housing for the chain, which is well sealed for shielding purposes, is not convenient to construct. Placing the chain between two large metal electrodes has the disadvantage that the electrodes must have a radius of curvature much larger than their separation distance. Thus, for a large voltage holdoff, the electrode size makes them necessarily expensive to construct and not very portable.

A method of providing a uniform electric field and graded stray capacitances around the resistive divider chain is by enclosing the high voltage chain inside a second resistive divider chain in a concentric cylindrical configuration. See Fig. 4a.[2] This allows the use of

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14. ABSTRACT
A simple, easily constructed, high voltage probe (~ 300 kV) with a good frequency response (~ 100 MHz) and high input impedance ~ 10 kn) is desirable in man.v applications. Such a probe, constructed of two concentric cylinders of "Velostat"l is reported.

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electrodes similar to but much smaller than those of Fig. 3b. The probe in Fig. 4a has an input impedance $\gtrsim$30 kΩ. It has a frequency response of $\gtrsim$200 MHz and can withstand voltage potentials of $\approx$100 kV in air or $\approx$300 kV if immersed in oil. Although the probe works very well, it has the disadvantages that the design requires special order resistors (5 ea: 10 kΩ, 11 J) with a long delivery time and that its initial construction is not simple, particularly because it is somewhat difficult to separate the oil and electrolyte and seal their reservoirs without trapping or forming bubbles. This compact arrangement is a big improvement over those of Fig. 3, but the probe is still not light, especially when immersed in oil. Finally, one is hesitant to measure the unknown voltage of a high energy source for fear of exceeding the probe's high voltage or power rating and damaging the unit.

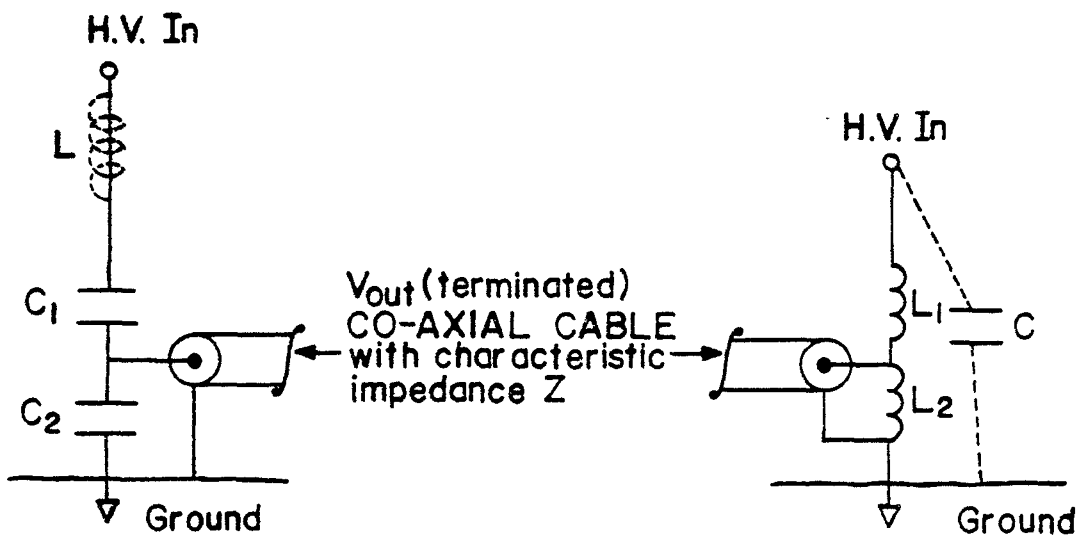
We, therefore, have built and tested a probe of the type shown in Fig. 4c, which has the distinct features of being simple (3 man-hours to assemble and ½ hour to repair) and inexpensive to construct, as well as, being very light and portable. It typically has a good high frequency response ($\lesssim$100 MHz) and is able to withstand $\gtrsim$300 kV without being immersed in oil. With a high input impedance ($\gtrsim$10 kΩ), it is a tool that would be very useful in many research applications. The design of the probe is very similar to the one shown in Fig. 4a except that Velostat[1] replaces the inner resistor divider chain and the electrolyte. Velostat is a trade name for polyolefin plastic that is made conductive by the addition of carbon. No oil or electrolyte is used. Velostat film is available in 150 ft rolls of 4, 6, and 8 mil thicknesses and several widths (36-72 in). "Velostat layflat tubing" with 4 and 8 mil thicknesses and widths varying from 3 to 12 in can be purchased in 500 ft rolls. Solid rod stock has diameters from 1/8 to 13/16 in. Also, the top metal electrodes of Fig. 3c may be replaced by thin metal sheets since there are no oil or electrolyte reservoirs to seal. Even aluminum foil may be used for the electrodes; this allows their diameter, d_3, to be varied for fine tuning the probe response.

Table I contains a comparison of various sizes and styles of the new probe design. The parameters listed are the dimensions indicated in Fig. 4c plus the limiting risetimes (t_r) of the different styles. The response of two of these probe styles (f), $\lesssim$300 kV, and (g), $\lesssim$50 kV, is compared to a calibrated input signal in Fig. 5. The inner Velostat cylinder of probe (f) will dissipate $\gtrsim$2 kJ of energy with only a 10% change in resistance ($\approx$10°C change).

References

1. "Velostat" - Trade name for polyolefin plastic that is made conductive by the addition of carbon. 3M Co., Nuclear Products Dept., 3M Center, St. Paul, Minnesota 55101.

2. Henins, I., Progress Report No. LA-5656-PR, Los Alamos Scientific Laboratories, Los Alamos, New Mexico 87544, July, 1974.



_if_ $Z \gtrsim 10 \dfrac{1}{C_2 \omega_{Min}}$

$$V_{out} = \frac{1/C_2}{1/C_1 + 1/C_2}$$

_if_ $Z \gtrsim 10\, \omega_{Max} L_2$

$$V_{out} = \frac{L_2}{L_1 + L_2}$$

Fig. 1. Capacitive and inductive voltage divider chains.

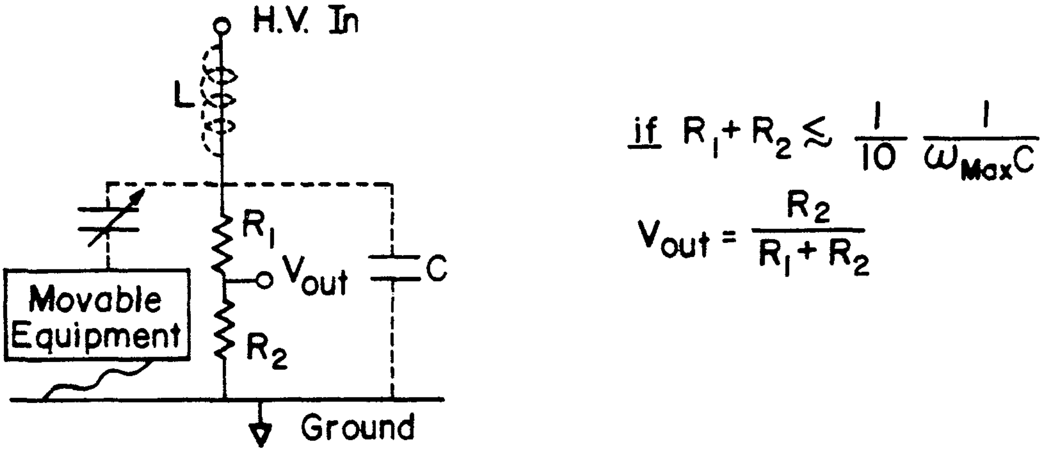


Fig. 2. Resistive divider chain.

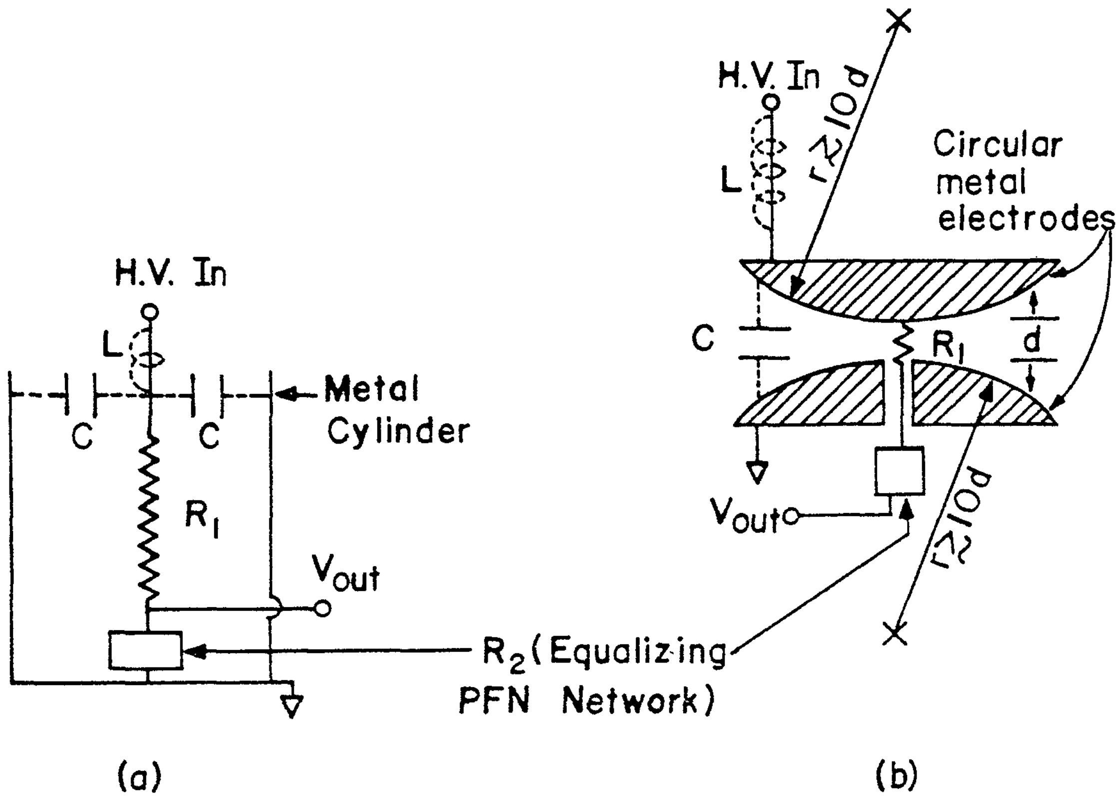


Fig. 3. Two methods of removing the variable capacitance in Fig. 2

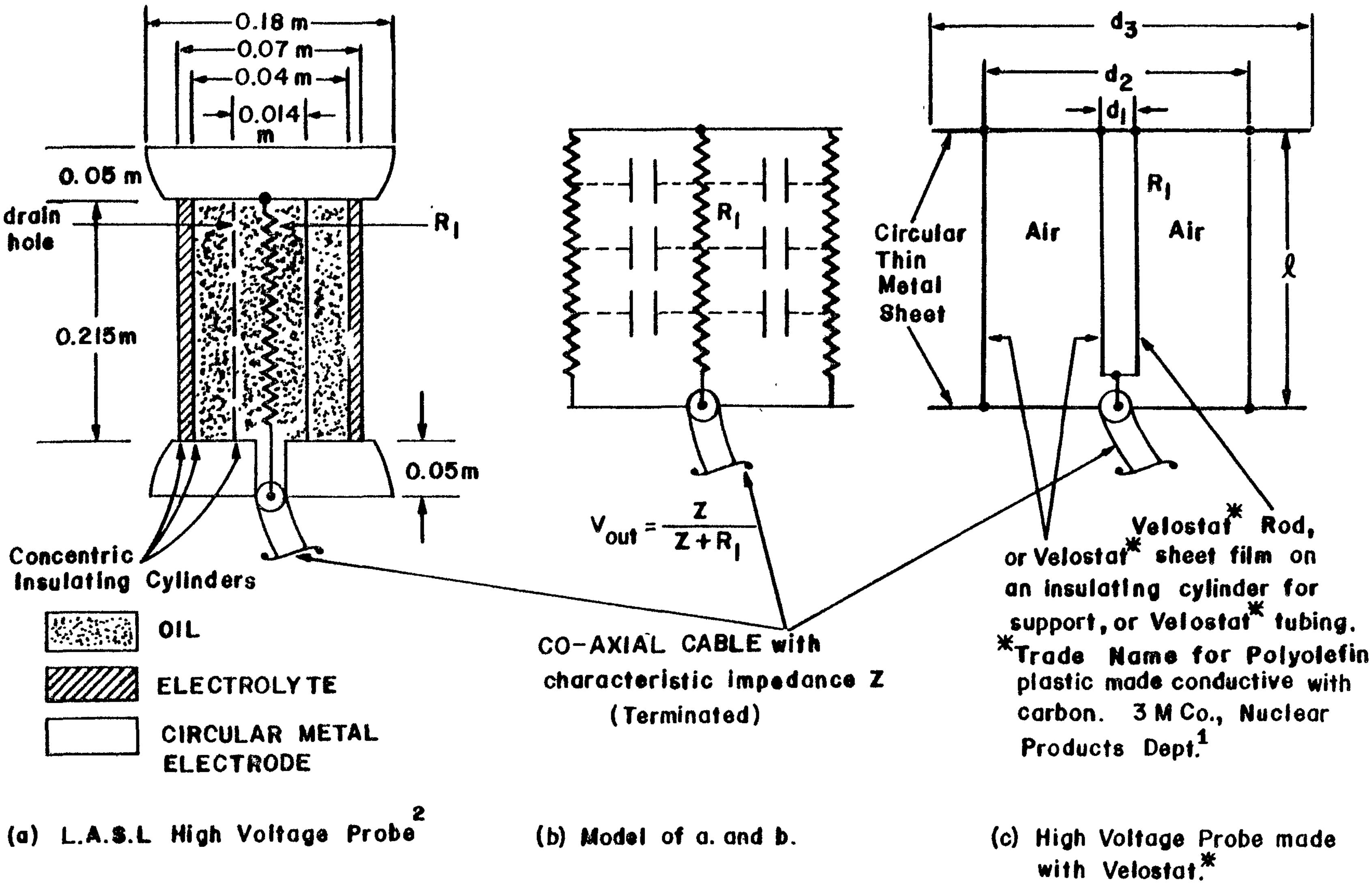


Fig. 4. Preferred methods for HV probe design.

Approximate Dimensions		d_1(m)	d_2(m)	d_3(m)	ℓ(m)	Risetime t_r
H.V. Probe made with 8 mil Velostat[1] film ($\frac{V_{in}}{V_{out}} \approx$ 1,500:1 $\rightarrow$ 3,000:1)	(a)	0.089	none	none	1.	$\gtrsim 3\mu S$
	(b)	0.089	0.091	none	1.	$\gtrsim$300nS
	(c)	0.089	0.091	~0.5	1.	$\gtrsim$200nS
	(d)	0.027	0.089	0.089	1.	$\gtrsim$100nS
	(e)	0.027	0.089	~0.5	1.	$\gtrsim$50nS
	(f)	0.027	0.16	~0.5	1.	$\gtrsim$20nS
	(g)	0.007	0.06	0.06	0.2	$\gtrsim$10nS
L.A.S.L. H.V. Probe[2] ($\frac{V_{in}}{V_{out}} \approx$ 1,000:1 $\rightarrow$ 2000:1)		0.008	~0.035	0.18	0.215	$\lesssim$10nS

Table I. Comparison of different probe styles.

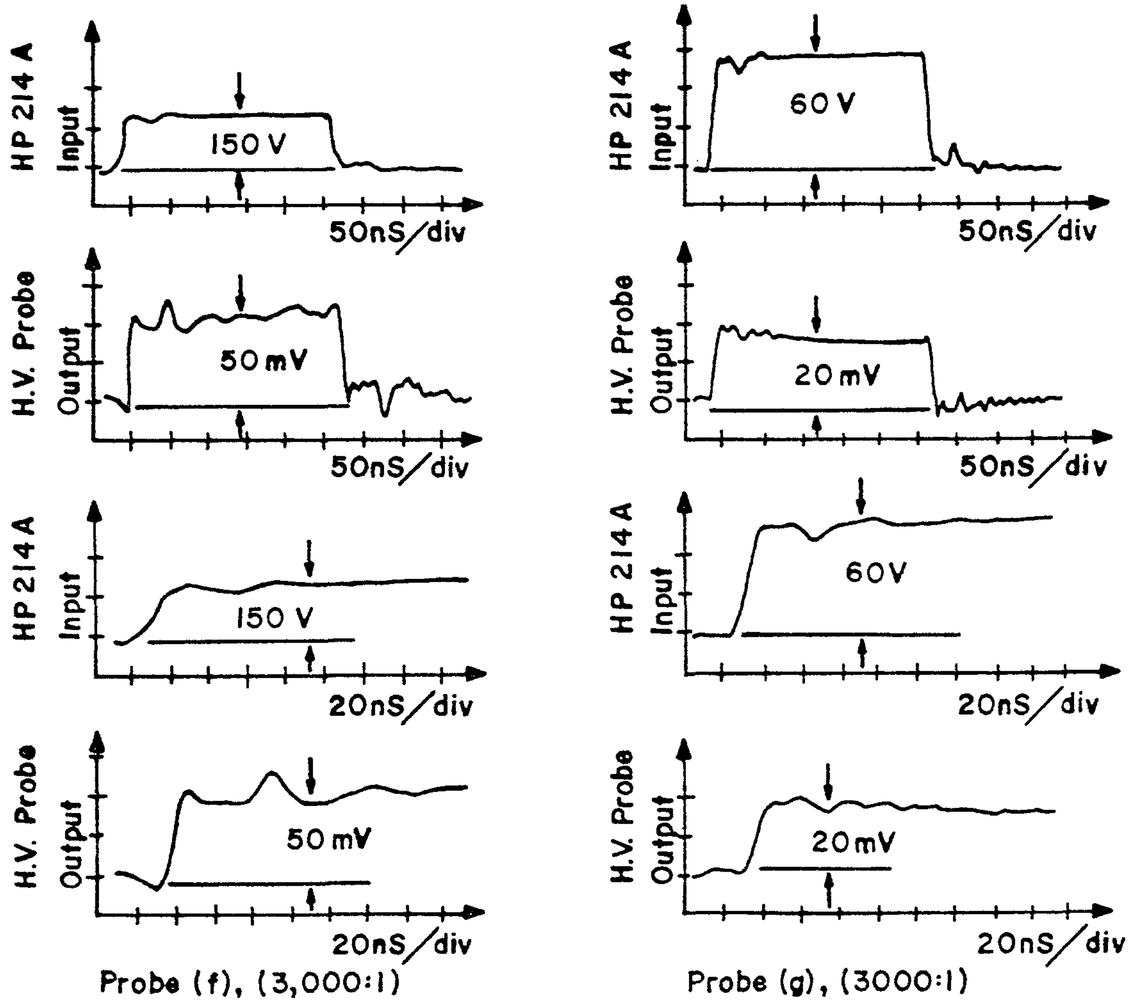


Fig. 5. Probe response to a calibrated input signal.